



An Analysis of Teleoperation Workload in Various Sensory Feedback Modes

David R. Scribner

ARL-TR-1114

SEPTEMBER 1996

Approved for public release; distribution is unlimited.

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

AN ANALYSIS OF TELEOPERATION WORKLOAD IN
VARIOUS SENSORY FEEDBACK MODES

David R. Scribner

September 1996

APPROVED: _____
ROBIN L. KEESEE
Director, Human Research &
Engineering Directorate

Approved for public release; distribution is unlimited.

U.S. ARMY RESEARCH LABORATORY

Aberdeen Proving Ground, Maryland

CONTENTS

INTRODUCTION	3
TELEOPERATED DRIVING MODEL ANALYSIS	5
Identification of Teleoperated Driving Functions and Tasks	5
MAN-SEVAL Modeling	8
Estimating Variance of Model Workloads	9
Data Generation of Different Sensory Feedback Modes	10
DATA ANALYSIS	10
RESULTS	10
F Tests	27
Post Hoc Analysis	27
CONCLUSIONS	29
RECOMMENDATIONS FOR FURTHER RESEARCH AND DEVELOPMENT ...	30
BIBLIOGRAPHY	33
APPENDICES	
A. McCracken-Aldrich Workload Scales	35
B. Workload Breakdown by Sensory Feedback Type	39
DISTRIBUTION LIST	53
FIGURES	
1. Mean and Range Values for Overall Workload with Homogeneous Grouping .	13
2. Mean and Range Values for Visual Workload with Homogeneous Grouping . .	16
3. Mean and Range Values for Auditory Workload with Homogeneous Grouping	19
4. Mean and Range Values for Cognitive Workload with Homogeneous Grouping	22
5. Mean and Range Values for Psychomotor Workload with Homogeneous Grouping	25
6. Mean and Range Values for Number of On-going Tasks with Homogeneous Grouping	28

TABLES

1. Functions and Tasks to Complete a Generic Teleoperated Driving Task	6
2. F Test for Overall Workload	11
3. Multiple Range Tests: Scheffé Test With Significance Level .05	11
4. Descriptive Statistics for All Groups, Overall Workload	12
5. Homogeneous Subsets for Overall Workload	12
6. F Test for Visual Workload	14
7. Scheffé Test With Significance Level .05, Visual Workload	14
8. Descriptive Statistics for All Groups, Visual Workload	15
9. Homogeneous Subsets for Visual Workload	15
10. F Test for Auditory Workload	17
11. Scheffé Test With Significance Level .05, Auditory Workload	17
12. Descriptive Statistics for All Groups, Auditory Workload	18
13. Homogeneous Subsets for Auditory Workload	18
14. F Test for Cognitive Workload	20
15. Scheffé Test With Significance Level .05, Cognitive Workload	20
16. Descriptive Statistics for All Groups, Cognitive Workload	21
17. Homogeneous Subsets for Cognitive Workload	21
18. F Test for Psychomotor Workload	23
19. Scheffé Test With Significance Level .05, Psychomotor Workload	23
20. Descriptive Statistics for All Groups, Psychomotor Workload	24
21. Homogeneous Subsets for Psychomotor Workload	24
22. F Test for Number of On-going Tasks Workload	26
23. Scheffé Test With Significance Level .05, Number of On-going Tasks Workload	26
24. Descriptive Statistics for All Groups, Number of On-going Tasks Workload .	27
25. Homogeneous Subsets for Number of On-going Tasks Workload	27

AN ANALYSIS OF TELEOPERATION WORKLOAD IN VARIOUS SENSORY FEEDBACK MODES

INTRODUCTION

The Teleoperated Interface Research Team of the Soldier-Systems Control Branch, Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory (ARL) has been involved with state-of-the-art teleoperated vehicles and control systems of various types for scientific study and performance enhancement. One objective of the research program at ARL is to survey all possible sensory feedback modes and to analyze them for their sensory immersion value, as reflected in performance measures of speed, error rate, control frequency response, and other stress, workload, and preference measures. ARL is currently the lead entity in the Army that is examining the optimization of teleoperator performance.

The different feedback modes available for study are stereovision (allowing true depth perception), binaural feedback from microphones on the teleoperated vehicle, color vision, expanded field of view (FOV), and simulated force feedback. Other modes such as low data rate (foveal windowing, reduced frame rate, reduced resolution, etc.), low bandwidth audio (sub-woofer frequencies), and the use of helmet-mounted displays are being examined as well but are not part of the scope of this paper.

The impetus for modeling different sensory feedback modes related to teleoperation began with the examination of manpower-based system evaluation aid (MAN-SEVAL), one of the hardware and manpower (HARDMAN) III software modules. HARDMAN III was a major development effort of the Army Research Institute's (ARI) System Research Laboratory and is now part of ARL (HRED). MAN-SEVAL is part of the HARDMAN III Government-owned software, which consists of a set of automated aids to assist analysts in conducting human factors assessments, including manpower, personnel, and training. MAN-SEVAL is a stochastic modeling environment that performs workload assessment analyses and manpower maintenance analyses. The workload analysis is the area of interest for this paper.

It appeared that MAN-SEVAL was capable of being used separately from the rest of the software modules as a modeling tool. The ability to define functions (groups of related tasks), tasks, workload (visual, cognitive, psychomotor, and auditory), and task times allowed the layout and examination of a workload and performance (time) model of the basic teleoperated driving task. It was realized that the tasks and workload could be altered, based on projected effect of different sensory feedback modes. Therefore, work began to attempt to capture, in

MAN-SEVAL, the workload associated with different sensory feedback modes. The workload associated with each (or a combination) of the feedback modes is seen to be an inverse relationship to performance in teleoperated driving. In other words, if the workload for a particular feedback mode is high, then the performance in that feedback mode will tend to improve. The performance of teleoperated tasks is the main research focus in the Teleoperated Interface Research Team at ARL.

The following is a list of the models built in the MAN-SEVAL modeling environment:

On-board driving model (baseline)

Teleoperated modes (different sensory feedback)

Low level (narrow FOV, monoscopic viewing, no audio or force feedback)

Binaural feedback

Simulated force feedback (in steering device)

Wide FOV (165°)

Stereoscopic vision

All feedback (combined)

The recent increases in quantity and quality of sensory feedback modes are to allow the operator to drive at higher speeds and during off-road conditions. These technical challenges were identified after Office of the Secretary of Defense demonstration of state-of-the-art robotics technology (OSD DEMO I) as critical teleoperator performance hurdles. The challenge to developing good teleoperated systems is the basic driving task, essential to the delivery or placement of the mission package; reconnaissance, surveillance, and target acquisition (RSTA); chemical detection; weapon system; or otherwise.

ARL is currently pursuing a research effort during which the sensory feedback modes will be examined to determine monetary cost, bandwidth transmission requirements, and operator performance changes. However, before this research effort, ARL's focus involved modeling the feedback modes and the resultant workload outcomes to form the beginnings of a predictive set of models with which to project performance changes as technologies impact the teleoperated system.

The purpose of this report is three-fold:

1. Define the functions and tasks of the teleoperated driver,
2. Assess the teleoperator's driving workload during conditions of varying sensory feedback, and

3. Provide a possible prediction tool for the impact of technology on teleoperation performance. Discussion will also encompass recommendations for further modeling development.

TELEOPERATED DRIVING MODEL ANALYSIS

Identification of Teleoperated Driving Functions and Tasks

Tasks are defined as the smallest single work units, depending upon the fidelity of the model, which are “mapped out” in order to understand a task network. Functions are related groups of tasks that are required to complete a part of the overall job. Driving functions (groups of related tasks) were identified through a task analysis of teleoperated driving tasks with the cooperation of resident ARL subject matter experts (SMEs) in the area of teleoperated driving and operations. The functions were then separated into discrete tasks (or relatively basic elements of work) that were required to complete the associated functions. All functions were sequenced according to logical flow as were all tasks associated with the functions. Task times were collected from a combination of interviews with ARL SMEs and the timing of simulated events as executed normally in driving operations. Note. Dummy functions or tasks are those non-data-generating functions or tasks incorporated into a network to maintain proper structure.

The following teleoperated driving functions were identified:

- Move to area of operations (dummy function)
- Conduct surveillance (of driving scene)
- Monitor vehicle instruments
- Monitor vehicle status
- Perform self-recovery
- Nothing happens (dummy function)
- Steer vehicle
- Power vehicle

Table 1 is a detailed list of the functions and tasks identified to complete a generic teleoperated driving task. Dummy functions or dummy tasks are those which were included but have no data to be processed or generated, they are there for the formation of the model structure only.

It was determined that the tasks in Table 1 had to be represented to a “deep” enough level to be sensitive enough to and reflect possible changes in mission task times and workload levels influenced by different technologies in the ARL teleoperated high mobility multipurpose wheeled vehicle (HMMWV). The next step in the process was to “move” the function and task data into the MAN-SEVAL environment.

Table 1

Functions and Tasks to Complete a Generic Teleoperated Driving Task

Functions	Tasks
Move to area of operations	Dummy function
Conduct surveillance	Conduct surveillance (dummy task) Detection of status change Alerted by external source Type of change? Course (dummy task) Is course in FOV? Course not in FOV Alter vehicle orientation Course in FOV Search (dummy task) Visual (dummy task) Look up Look down Look left Look right Auditory Dummy ID course? Does ID course Does not ID course On course Not on course Consult navigational aid ID potential obstacles and hazards? Does ID hazards Does not ID hazards Hazard immediate threat? Immediate threat, alter course Not immediate threat
Monitor vehicle instruments	Monitor Instruments (dummy task) Frequent (dummy task) Infrequent (dummy task) Monitor speedometer Monitor tachometer Monitor fuel level Monitor oil pressure Monitor engine temperature

Table 1 (continued)

	Monitor battery voltage Verify normal range Normal range Not normal range Stop vehicle and monitor
Monitor vehicle status	Monitor vehicle status (dummy task) Monitor vehicle pitch Monitor vehicle roll Vehicle attitude in normal range? Normal range Not normal range Stop vehicle and correct vehicle attitude Monitor engine speed Engine speed in normal operation? Normal Not normal Slow or stop vehicle and check Monitor ground surface Ground surface suitable for travel? Suitable Not suitable Change course (dummy task)
Perform self-recovery	Perform self-recovery Need to change direction? Change needed Look to sides and estimate correction Change not needed Need to reverse direction? Reverse needed Look to rear, back up Change direction Reverse not needed Proceed
Nothing happens	(dummy function)
Steer vehicle	Steer vehicle (dummy task) Steer right Steer left Hold straight Let steering self-center Verify center position Verify steering control action

Table 1 (continued)

Power vehicle	Power vehicle (dummy task)
	Accelerator (dummy task)
	Apply accelerator
	Hold accelerator
	Release accelerator
	Verify accelerator action
	Brake (dummy task)
	Apply brake
	Hold brake
	Release brake
	Verify brake action

MAN-SEVAL Modeling

This section describes how MAN-SEVAL is used. A description of all the steps required to build, run, and analyze models built in MAN-SEVAL follows, but first, a little bit about the major components of the modeling software is presented.

MAN-SEVAL was used to assess workload of the teleoperated driving task. The MAN-SEVAL workload assessment aid integrates two essential technologies, Micro Saint software simulation and the McCracken-Aldrich workload assessment methodology. Micro Saint (built by Micro Analysis & Design) is used to build and execute task network models that simulate operational procedures. Each task within the network is assigned to an operator. The McCracken-Aldrich workload assessment methodology is used to assess the visual, auditory, cognitive, and psychomotor workload components for each crew member. Each task is assigned a scaled value for each of the four workload components. When the simulation is run, the guard's workload is traced over time and then graphed. The model allows easy identification of high or low workload periods. The McCracken-Aldrich workload scales are presented in Appendix A of this report.

The steps for conducting a MAN-SEVAL workload analysis are as follow:

1. Define Conditions. The conditions during which the teleoperated driving mission will be performed are documented.
2. Develop Function List. All possible functions that the teleoperator may perform are listed. They are normally placed in sequence as they would be performed during actual operations.

3. Develop Task List. All possible tasks that the teleoperator may be required to perform are listed and sequenced as they would be completed during actual operations.

4. Identify Crew Positions. The driver is the only position listed.

5. Assign Tasks to Jobs. Two things are done here. All crew members capable of performing each task are identified, and then each task is assigned to one specific crew member. In this analysis, all tasks were assigned to the teleoperated driver.

6. Define Performance Parameters. Several things are done here. All tasks are assigned a most likely and a fastest time. Each task is then assigned workload scale values for visual, auditory, cognitive, and psychomotor workload channels. The workload scale values are derived from the McCracken-Aldrich workload assessment methodology. Finally, a high workload level is mathematically defined by the user.

7. Execute Simulation Run. Using Micro Saint, the task network simulation mode is run.

8. Analyze Results. Workload graphs depicting each crew member's workload in each workload channel are developed over time. High workload tasks are displayed and can be reallocated to other crew members automatically or manually when possible. Summary reports (e.g., percentage of time a high workload condition is experienced for each crew member) are also available.

Estimating Variance of Model Workloads

For each model developed, workload level and task time estimates were collected from HRED SMEs and from estimated scaling by using the descriptors of different workload channel tasks as described in the McCracken-Aldrich workload scale residing in the MAN-SEVAL software.

It is especially important to note that the workload scalings in the McCracken-Aldrich workload rating system are comprised of 8 points from 0 through 7, each with a different interval spacing. These workload ratings are established as interval data and have been validated by leading workload experts.

The workload levels for each channel were identified and set for the first model built or the low level feedback teleoperation model. Then, each task in each function was evaluated for a potential in workload reduction, based on the sensory feedback being examined. If the task was identified as one being affected by the sensory feedback technology, the workload level was

adjusted accordingly, either up or down each individual scale. The actual workload levels are listed in Appendix B. It is equally important that the reader understand that the workload adjustments in each model and the resultant output data be treated as an ordinal relationship. This will be mentioned again further in this report. The potential problem with the use of MAN-SEVAL is the forced usage of specific scale ratings, so that if a task were presumed to become easier, the next lower workload value may have been scaled lower in that subscale. Workload adjustments are subjective in nature and do not carry the confidence of true physiological workload data collection.

Data Generation of Different Sensory Feedback Modes

Data were generated from multiple runs of each sensory feedback model. Each model was run a total of 30 iterations. The criterion for accepting model output for each execution was that the overall task time be within one standard deviation (SD) of actual mean test course completion times for that mode of operation (i.e., on board or teleoperated). The mean course completion times were 3 and 6 minutes for on-board and teleoperated runs, respectively. Data for each workload channel were collected in the form of mean workload.

Each model was run six times (30 iterations per run) to collect workload information. Workload channel data were collected at 1/5-second intervals, as output in MAN-SEVAL, thus producing between 850 and 1800 data points for each workload channel, for each run.

DATA ANALYSIS

Mean workload values for iterative model runs were used as the final data that were examined to determine if any differences existed among the data. A one-way analysis of variance (ANOVA), with an F test was used to determine if there were any significant differences among the seven different models run for each of four workload channels (visual, auditory, cognitive, and psychomotor), as well as overall workload, which was the sum of all workload channels. A Scheffé post hoc test was used to determine if mean differences were significant between all teleoperated models where significance dictated.

RESULTS

Note. Before the results of these data are reviewed, it is important to consider the results of the on-board versus teleoperated means in the following data sets if nonsignificant differences occur. This is so because of the differences between on-board driving and teleoperated driving.

A nonsignificant result is one in which there is marked similarity between the workload of that teleoperated feedback and on-board driving, which is desirable. However, among teleoperated means, significant differences are important to note. Additionally, when data (workload means) are plotted or depicted graphically, the lesser workload condition is desired.

The results of data analysis for overall workload are presented in Tables 2 through 5.

Table 2

F Test for Overall Workload

Source	df	SS	s2	F ratio	Critical F value	Prob. F
Between	6	515.39	85.89	9.89	2.38 (.05)	.0000
Within	35	303.73	8.67		3.38 (.01)	
Total	41	819.13				

Table 3

Multiple Range Tests: Scheffé Test With Significance Level .05

		Group							
		1	6	7	2	5	4	3	
(On-board)	1								
(Wide FOV)	6								
(All feedback)	7								
(Low level)	2	*							
(stereovision)	5	*							
(force fdbk)	4	*							
(binaural)	3	*	*						

The difference between two means is significant if
 $MEAN(J) - MEAN(I) \geq 2.0831 * RANGE * \sqrt{1/N(I) + 1/N(J)}$
 with the following value(s) for RANGE: 5.33

*Indicates significant differences

Table 4

Descriptive Statistics for All Groups, Overall Workload

Group	n	Mean	Deviation	Minimum	Maximum
On-board	6	31.30	1.07	30.00	32.65
Low level	6	39.18	3.21	33.11	42.69
Binaural	6	42.34	2.54	38.49	45.86
Force Fdbk	6	40.37	2.64	36.42	44.35
Stereo	6	39.77	3.75	33.59	42.80
Wide FOV	6	34.97	1.54	33.01	36.49
All Fdbk	6	36.18	4.40	28.89	41.81

Table 5

Homogeneous Subsets for Overall Workload

Subset 1	1,6,7
Subset 2	6,7,2,5,4
Subset 3	7,2,5,4,3

The overall mean workload comparisons and homogeneous groups for all feedback modes are graphically depicted in Figure 1.

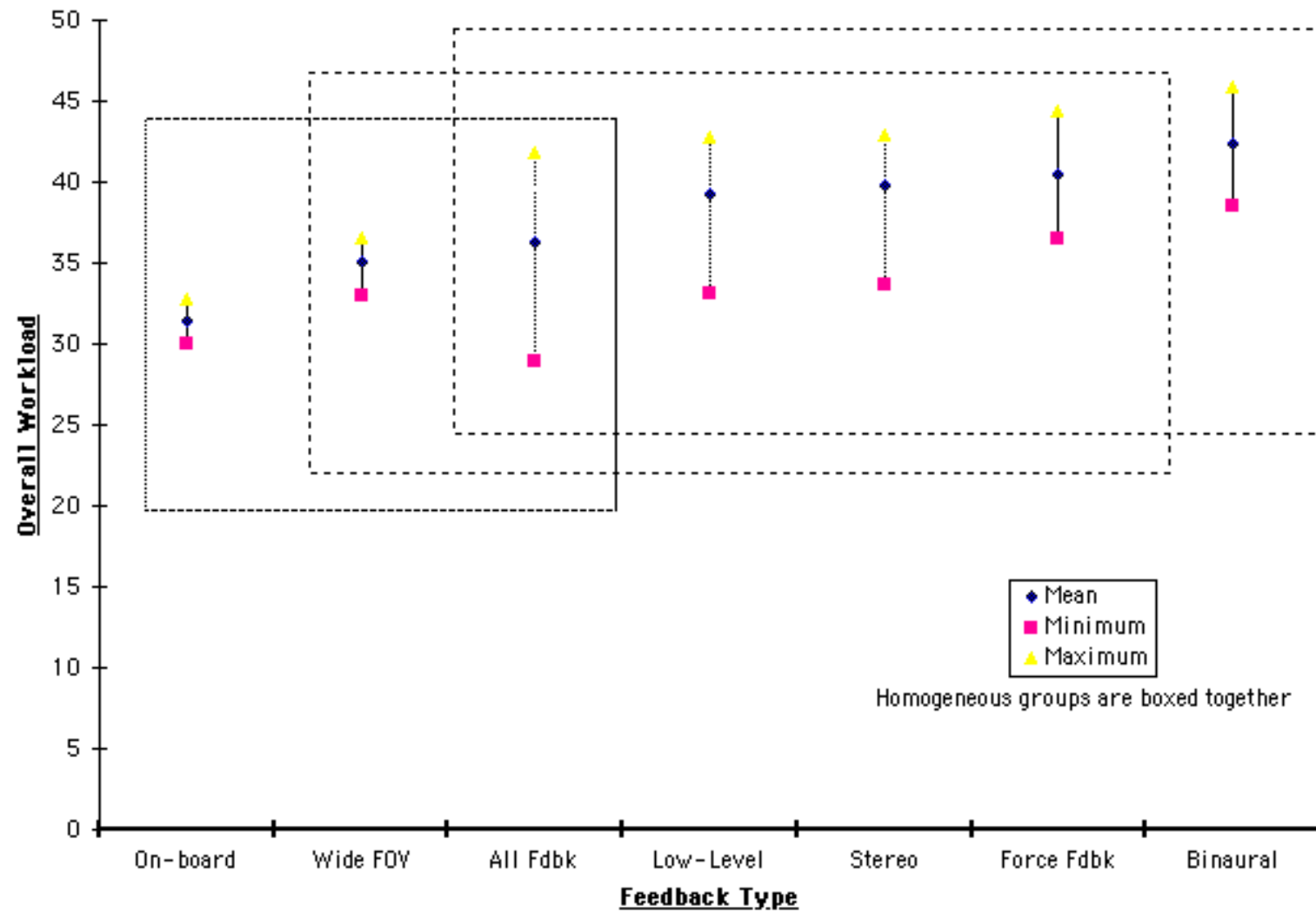


Figure 1. Mean and range values for overall work load with homogeneous grouping.

The results of data analysis for visual workload are presented in Tables 6 through 9.

Table 6

F Test for Visual Workload

Source	df	SS	s2	F ratio	Critical F value	Prob. F
Between	6	114.65	19.10	9.15	2.38 (.05)	.0000
Within	35	73.05	2.08		3.38 (.01)	
Total	41	187.71				

Table 7

Scheffé Test With Significance Level .05, Visual Workload

		Group						
		1	7	6	5	3	2	4
(On-board)	1							
(All feedback)	7							
(Wide FOV)	6							
(binaural)	5	*						
(low level)	3	*						
(force fdbk)	2	*						
(Stereo)	4	*	*					

The difference between two means is significant if
 $MEAN(J) - MEAN(I) \geq 1.02 * RANGE * \sqrt{1/N(I) + 1/N(J)}$
 with the following value(s) for RANGE: 5.33

*Indicates significant differences

Table 8

Descriptive Statistics for All Groups, Visual Workload

Group	n	Mean	Deviation	Minimum	Maximum
On-board	6	12.11	.50	11.38	12.95
Low level	6	17.02	1.98	13.14	18.76
Binaural	6	15.62	.72	14.56	16.54
Force fdbk	6	17.29	1.50	14.42	18.57
Stereo	6	15.50	1.83	12.88	17.32
Wide FOV	6	15.02	.69	13.94	15.62
All fdbk	6	13.94	1.93	11.31	16.07

Table 9

Homogeneous Subsets for Visual Workload

Subset 1	1,7,6
Subset 2	7,6,5,3,2
Subset 3	6,5,3,2,4

The visual workload comparisons and homogeneous groups for all feedback modes are graphically depicted in Figure 2.

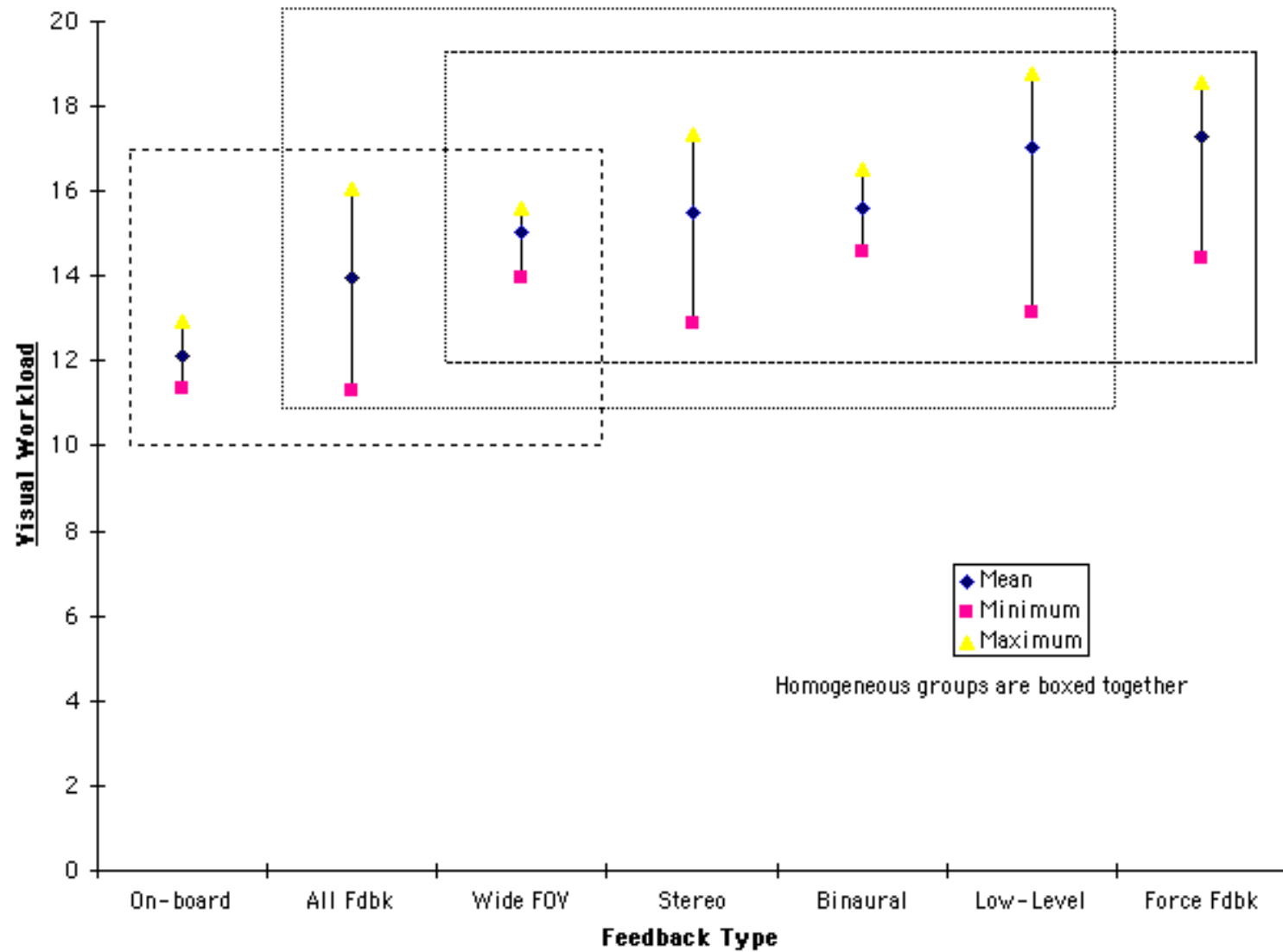


Figure 2. Mean and range values for visual work load with homogeneous grouping.

The results of data analysis for auditory workload are presented in Tables 10 through 13.

Table 10

F Test for Auditory Workload

Source	df	SS	s2	F ratio	Critical F value	Prob. F
Between	6	75.88	12.64	106.24	2.38 (.05)	.0000
Within	35	4.16	.11		3.38 (.01)	
Total	41	80.05				

Table 11

Scheffé Test With Significance Level .05, Auditory Workload

		2	4	5	Group 6	1	7	3
(force fdbk)	2							
(Stereo)	4							
(binaural)	5							
(Wide FOV)	6							
(On-board)	1							
(All feedback)	7							
(low level)	3	*	*	*	*	*	*	*

The difference between two means is significant if
 $MEAN(J) - MEAN(I) \geq .24 * RANGE * \sqrt{1/N(I) + 1/N(J)}$
 with the following value(s) for RANGE: 5.33

*Indicates significant differences

Table 12

Descriptive Statistics for All Groups, Auditory Workload

Group	n	Mean	Deviation	Minimum	Maximum
On-board	6	1.38	.15	1.28	1.68
Low level	6	1.00	.00	1.00	1.00
Binaural	6	4.95	.87	3.80	6.22
Force fdbk	6	1.00	.00	1.00	1.00
Stereo	6	1.00	.00	1.00	1.00
Wide FOV	6	1.00	.00	1.00	1.00
All fdbk	6	1.00	.18	1.43	1.95

Table 13

Homogeneous Subsets for Auditory Workload

Subset 1	2,4,5,6,1
Subset 2	3

The auditory workload comparisons and homogeneous groups for all feedback modes are graphically depicted in Figure 3.

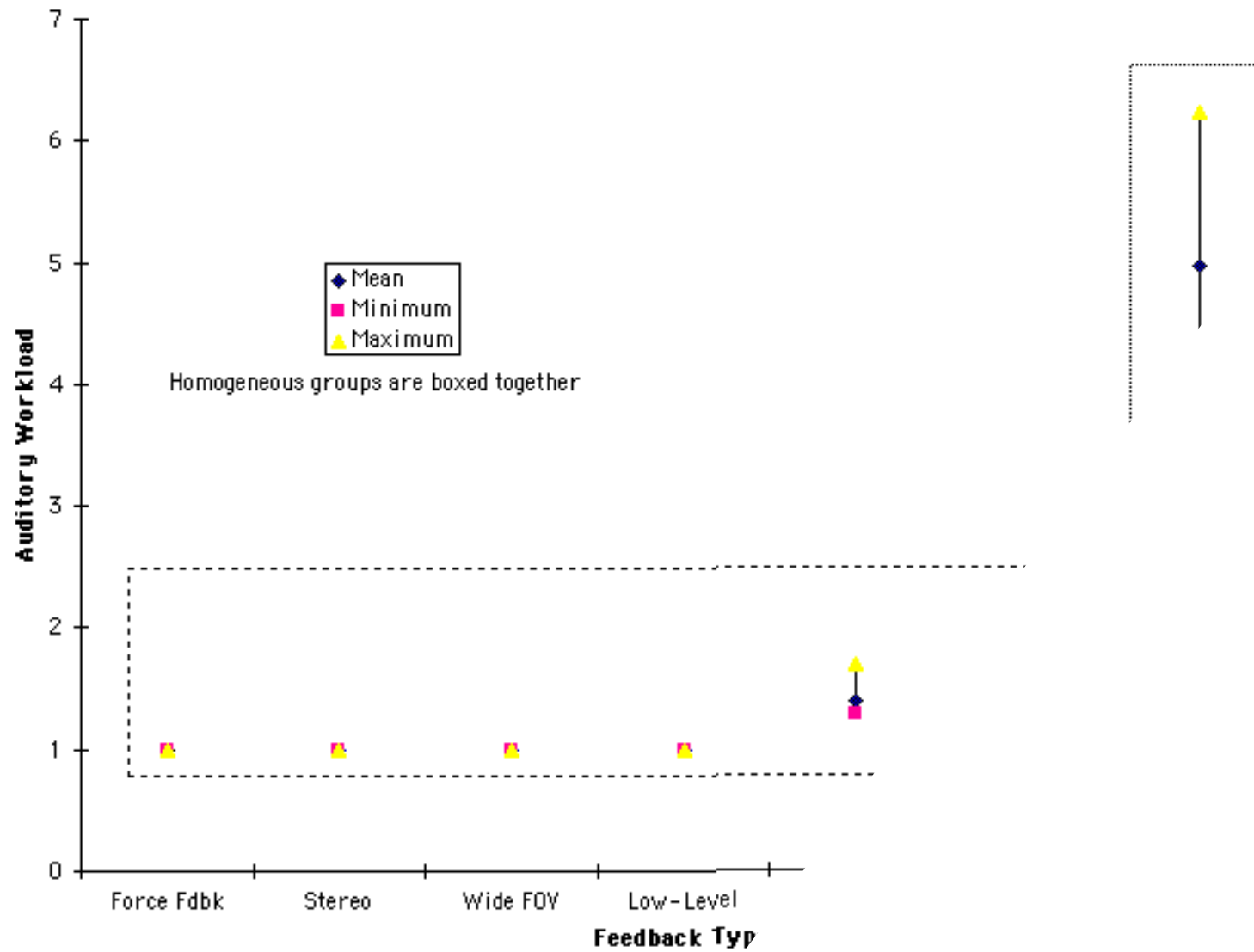


Figure 3. Mean and range values for auditory work load with homogeneous grouping.

The results of data analysis for cognitive workload are presented in Tables 14 through 17.

Table 14

F Test for Cognitive Workload

Source	df	SS	s2	F ratio	Critical F value	Prob. F
Between	6	226.20	37.70	29.73	2.38 (.05)	.0000
Within	35	44.37	1.26		3.38 (.01)	
Total	41	270.57				

Table 15

Scheffé Test With Significance Level .05, Cognitive Workload

		Group							
		1	6	7	3	4	2	5	
(On-board)	1								
(Wide FOV)	6	*							
(All feedback)	7	*							
(Low level)	3	*	*						
(stereovision)	4	*	*						
(force fdbk)	2	*	*						
(binaural)	5	*	*	*					

The difference between two means is significant if
 $MEAN(J) - MEAN(I) \geq .79 * RANGE * \sqrt{1/N(I) + 1/N(J)}$
 with the following value(s) for RANGE: 5.33

*Indicates significant differences

Table 16

Descriptive Statistics for All Groups, Cognitive Workload

Group	n	Mean	Deviation	Minimum	Maximum
On-board	6	9.39	.54	8.89	10.34
Low level	6	15.49	.73	14.69	16.81
Binaural	6	14.63	1.14	12.82	15.89
Force fdbk	6	15.11	.91	14.16	16.79
Stereo	6	16.85	1.77	13.86	18.17
Wide FOV	6	12.01	.58	11.49	12.85
All fdbk	6	13.15	1.55	10.70	14.83

Table 17

Homogeneous Subsets for Cognitive Workload

Subset 1	1
Subset 2	6,7
Subset 3	7,3,4,2
Subset 4	3,4,2,5

The cognitive workload comparisons and homogeneous groups for all feedback modes are graphically depicted in Figure 4.

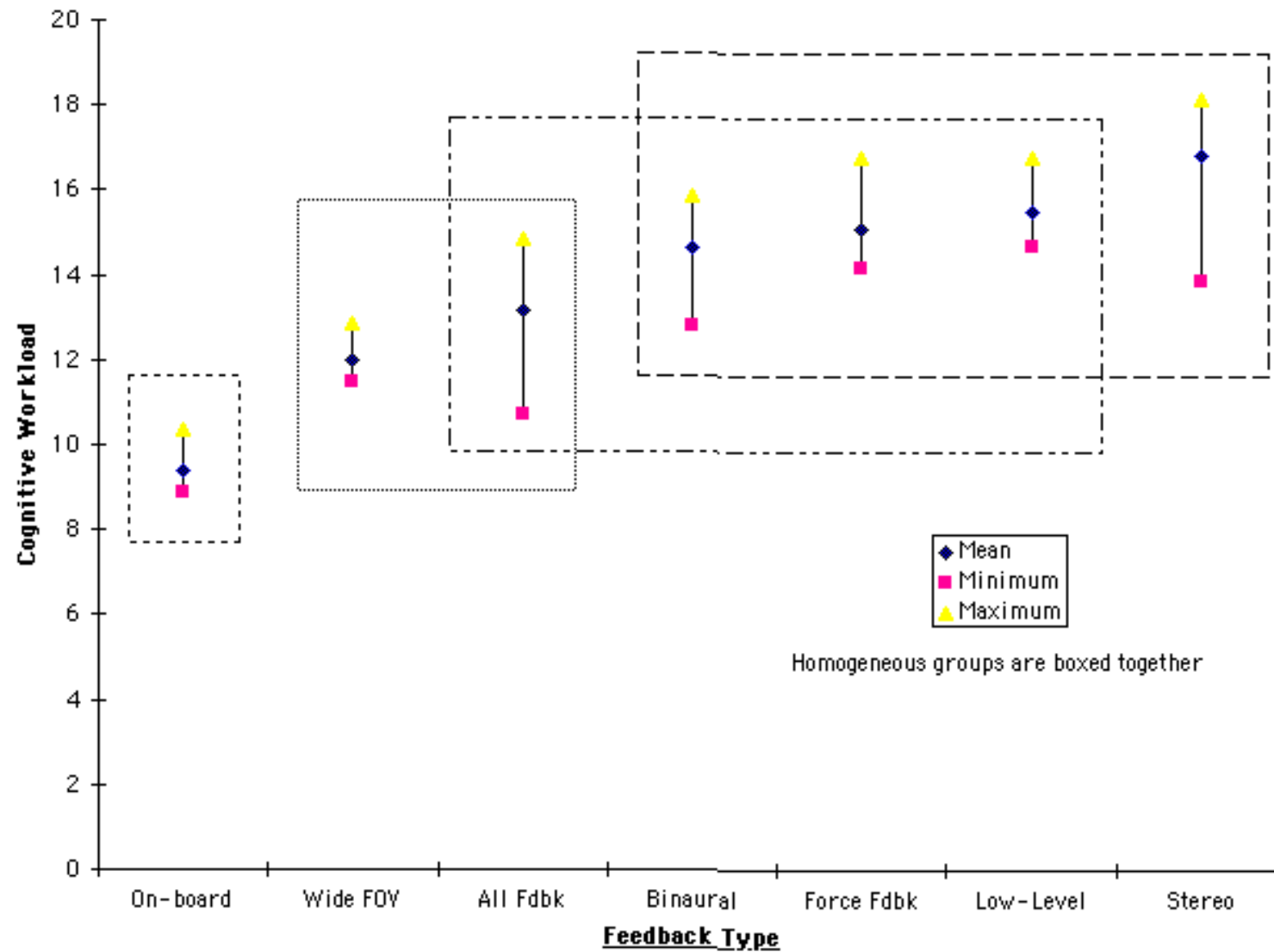


Figure 4. Mean and range values for cognitive work load with homogeneous grouping.

The results of data analysis for psychomotor workload are presented in Tables 18 through 21.

Table 18
F Test for Psychomotor Workload

Source	df	SS	s2	F ratio	Critical F value	Prob. F
Between	6	114.65	19.10	9.15	2.38 (.05)	.0000
Within	35	73.05	2.08		3.38 (.01)	
Total	41	187.71				

Table 19
Scheffé Test With Significance Level .05, Psychomotor Workload

		2	5	6	Group 4	3	7	1
(force fdbk)	2							
(binaural)	5							
(Wide FOV)	6							
(Stereo)	4							
(low level)	3							
(All feedback)	7	*						
(On-board)	1	*	*					

The difference between two means is significant if
 $\text{MEAN}(J) - \text{MEAN}(I) \geq .52 * \text{RANGE} * \text{SQRT}(1/N(I) + 1/N(J))$
 with the following value(s) for RANGE: 5.33

*Indicates significant differences

Table 20

Descriptive Statistics for All Groups, Psychomotor Workload

Group	n	Mean	Deviation	Minimum	Maximum
On-board	6	8.41	.10	8.28	8.60
Low-Level	6	5.66	.73	4.27	6.41
Binaural	6	7.13	.54	6.57	8.13
Force Fdbk	6	6.97	.88	5.93	7.97
Stereo	6	6.41	.47	5.85	7.30
Wide FOV	6	6.96	.69	5.85	8.03
All Fdbk	6	7.37	1.25	5.42	9.05

Table 21

Homogeneous Subsets for Psychomotor Workload

Subset 1	2,5,6,4,3
Subset 2	5,6,4,3,7
Subset 3	6,4,3,7,1

The psychomotor workload comparisons and homogeneous groups for all feedback modes are graphically depicted in Figure 5.

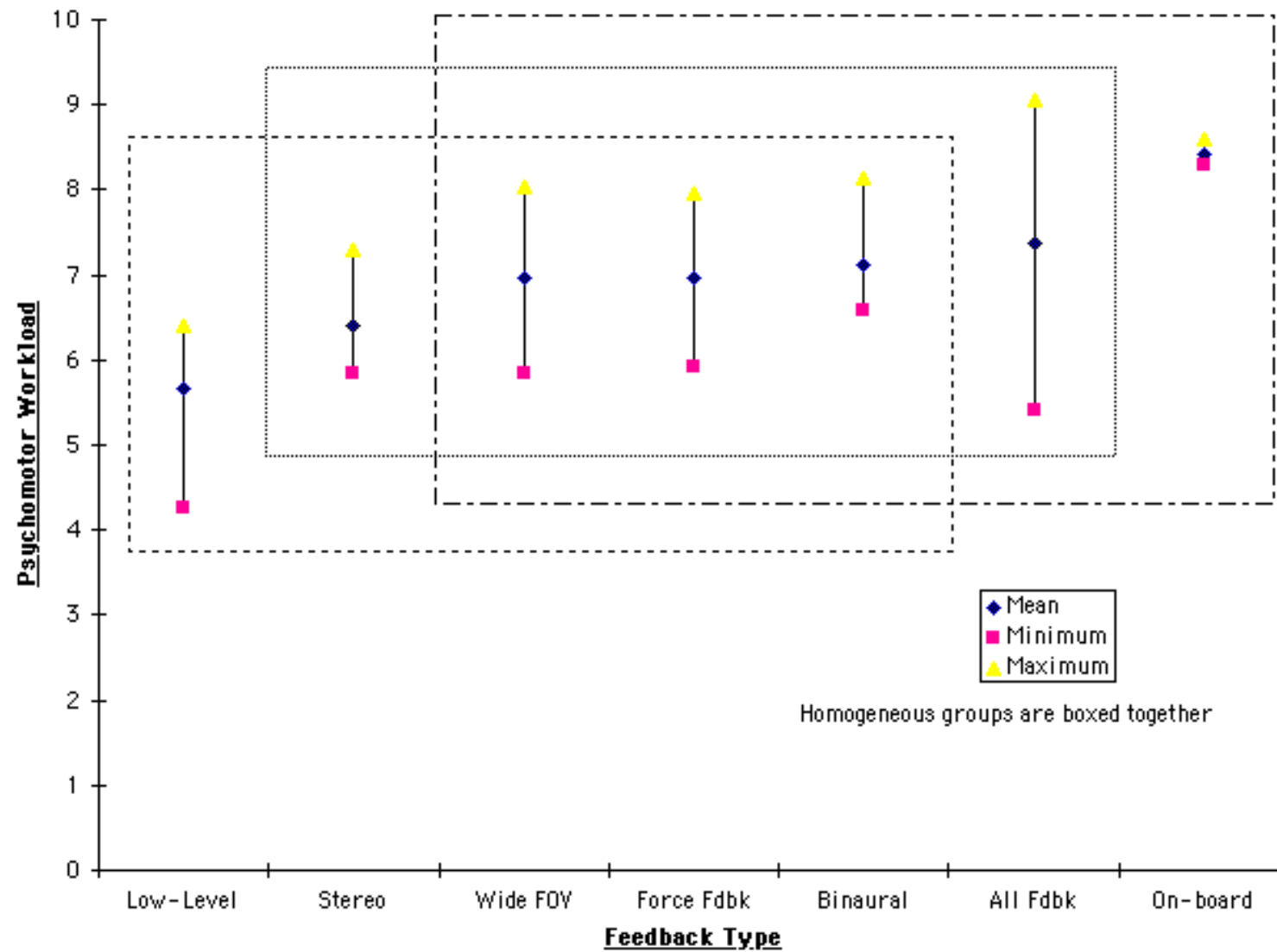


Figure 5. Mean and range values for psychomotor work load with homogeneous grouping.

The results of data analysis for number of on-going tasks workload are presented in Tables 22 through 25.

Table 22

F Test for Number of On-going Tasks Workload

Source	df	SS	s2	F ratio	Critical F value	Prob. F
Between	6	2.07	.34	4.51	2.38 (.05)	.0095
Within	35	1.07	.07		3.38 (.01)	
Total	41	3.14				

Table 23

Scheffé Test With Significance Level .05, Number of On-going Tasks Workload

		6	2	3	Group 5	4	1	7
(Wide FOV)	6							
(force fdbk)	2							
(low level)	3							
(binaural)	5							
(Stereo)	4							
(On-board)	1							
(All feedback)	7	*						

The difference between two means is significant if
 $\text{MEAN}(J) - \text{MEAN}(I) \geq .19 * \text{RANGE} * \text{SQRT}(1/N(I) + 1/N(J))$
 with the following value(s) for RANGE: 5.85

*Indicates significant differences

Table 24

Descriptive Statistics for All Groups, Number of On-going Tasks Workload

Group	n	Mean	Deviation	Minimum	Maximum
On-board	6	5.19	.01	5.18	5.21
Low level	6	4.64	.16	4.54	4.83
Binaural	6	4.80	.16	4.65	4.97
Force fdbk	6	4.95	.22	4.69	5.09
Stereo	6	4.88	.48	4.40	5.37
Wide FOV	6	4.60	.36	4.18	4.85
All fdbk	6	5.57	.26	5.30	5.82

Table 25

Homogeneous Subsets for Number of On-going Tasks Workload

Subset 1	6,2,3,5,4
Subset 2	2,3,5,4,1,7

The visual workload comparisons and homogeneous groups for all feedback modes are graphically depicted in Figure 6.

F Tests

F tests revealed significant differences for all workload channels, including overall workload and number of on-going tasks. All ANOVAs yielded F ratios that were significant to the .01 level. The Scheffé Test was used to perform group mean post hoc comparisons:

Post Hoc Analysis

For overall workload, the Scheffé Test showed that *on-board* was significantly different from *low level*, *stereo*, *force feedback* and *binaural* to the .05 level. *Wide field of view* was also significantly different from *binaural* to the .05 level. *On-board*, *wide FOV*, and *all feedback* conditions were not statistically different from each other, and were identified as a homogeneous group, where the highest and lowest means are not significantly different.

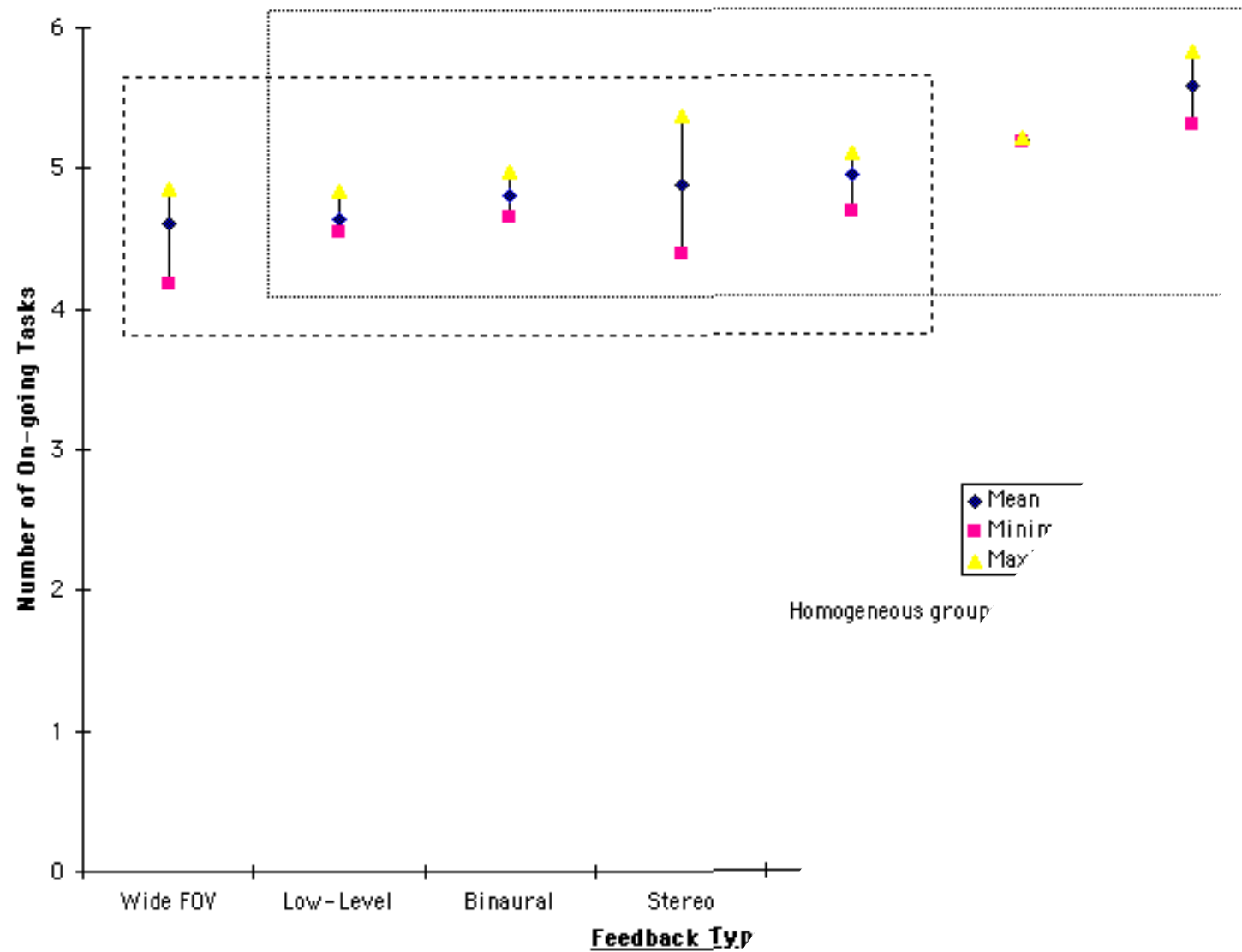


Figure 6. Mean and range values for number of on-going tasks with homogeneous grouping.

For visual workload, the Scheffé Test showed that *on-board* was significantly different from *low level*, *stereo*, *force feedback*, and *binaural* to the .05 level. *All feedback* was also significantly different from *force feedback* to the .05 level. *On-board*, *wide FOV*, and *all feedback* conditions were not statistically different from each other and were identified as a homogeneous group, in which the highest and lowest means are not significantly different.

For auditory workload, the Scheffé Test showed that *binaural feedback* was significantly different from all other conditions to the .05 level.

For cognitive workload, the Scheffé Test showed that *on-board* was significantly different from all other conditions to the .05 level. *Wide field of view* was also significantly different from *binaural*, *force feedback*, *low level*, and *stereo* to the .05 level. Additionally, *all feedback* was significantly different from *stereo* to the .05 level. *Wide FOV* and *all feedback* conditions were not statistically different from each other and were identified as a homogeneous group, in which the highest and lowest means are not significantly different. *On-board* was identified as a single homogeneous group.

For psychomotor workload, the Scheffé Test showed that *low level* was significantly different from *all feedback* and *on-board* to the .05 level. *Stereo* was also significantly different from *on-board* to the .05 level. *On-board*, *binaural*, *force feedback*, and *wide field of view* conditions were not statistically different from each other and were identified as a homogeneous group, in which the highest and lowest means are not significantly different.

For number of on-going tasks, the Scheffé Test showed that *wide field of view* was significantly different from *all feedback* to the .05 level. *All feedback*, *on-board*, *force feedback*, *stereo*, *binaural*, and *low level* conditions were not statistically different from each other and were identified as a homogeneous group, in which the highest and lowest means are not significantly different.

CONCLUSIONS

Upon examination of the F Test results and the post hoc mean comparisons of the different model group means, it can be seen that a definite trend occurred in the data. It appears that the data for *wide FOV* and the *all feedback* models were similar to those of *on-board* driving with respect to overall and visual workload. Additionally, *wide FOV* and *all feedback* were significantly different from the other teleoperated feedback (*binaural*, *force feedback*, *low level*,

and stereo), even though different from on-board data for cognitive workload. The best evidence of this is seen by examining the graphical representations of the data (see Figures 1 through 6).

The reason for the similarities of the modeled data among *on-board*, *wide FOV*, and *all feedback* models appears to be because of the number of tasks that are affected by the feedback. The feedback qualities of the modeled conditions are similar because of the task workload similarity. Using the *on-board* model as a baseline comparison, *wide FOV* and *all feedback* data seem to be worth examining through the use of further modeling and model validation via field data collection during teleoperated driving conditions.

The author believes that the utility of the *wide FOV* and of course, the *all feedback* models, is for the most part, supported by the relevant scientific literature. The *all feedback* model is of particular concern for future modeling efforts because of the potentially strong effect of combining all possible feedback modes.

The author further believes that the modeled combination of all feedback modes, except for binaural (auditory) feedback, would have yielded stronger results beyond those reflected for *wide field of view* and *all feedback* combined. This hypothesized effect is expected because of the relatively high overall workload seen in the binaural feedback condition.

In the future, factorial analysis of the effects of different combinations of sensory feedback modes will benefit those teleoperated systems developers looking for the right mix of sensory feedback, for the particular task needs of the system. It is believed that in order to learn more about the interaction effects of all feedback scenarios, a factorial design or a specially selected set of feedback combinations for workload comparison should be tried in the future.

Overall, the confidence in the “generality” of the overall workload data is high, because of the examination of workload for each operator task and the common sense approach to sensory feedback modes. However, specific workload data to be used for the purpose of equipment design or fabrication would be foolhardy without model validation through the comparison of real workload data.

RECOMMENDATIONS FOR FURTHER RESEARCH AND DEVELOPMENT

- A. Collect real task times from soldiers in the user population.

To enhance the fidelity of the models herein and in the future, it is suggested that task times to be included in the MAN-SEVAL models be collected from a large pool of actual system users. The task times from the larger pool of real users should prove to be more stable estimates. A current ARL effort with the project manager of unmanned ground vehicles (PMUGV) will accomplish this.

B. Verify the workload ratings of teleoperated tasks in MAN-SEVAL.

A truer method of estimating workload from different types of tasks should be included in the McCracken-Aldrich workload scales. A listing of all teleoperated tasks as they relate precisely to the workload scales should be developed for future modeling. Presently, tasks must be identified and a similar but not exact task is given in the workload scales. This would require the consultation of a workload expert.

C. Performing Maintenance and RSTA mission modeling.

RSTA should be examined in future modeling efforts to provide a more complete approach to the area of teleoperated mission and payload operation.

Additionally, it has been suggested that a maintenance workload and task time model be developed along with mission-oriented clothing restrictions as variations of the maintenance models (mission-oriented protective posture [MOPP] and arctic clothing). This will be performed in the near future by ARL to support PMUGV efforts.

D. Develop a common workload measure for data transfer from experimental to modeling environments.

Compare any experimental data findings with modeled predictions to determine if the modeling effort established in this report can be validated or verified. This may also encompass the use of a workload rating system such as the National Aeronautics and Space Administration (NASA) task load index (TLX) or other measures to successfully capture the four channels of workload as used in MAN-SEVAL. NASA TLX data can be transformed into “overall workload” data. However, there is no direct or standardized workload format. Such a format is needed to transfer common workload measures from the experimental situation into the modeling situation.

An effort to begin investigation in this area, which will be fostered by a Phase II small business innovative research (SBIR) contract, is progressing at ARL.

BIBLIOGRAPHY

- Dahl, S. (1996). Manpower-based system evaluation aid (MAN-SEVAL) (Contractor Report ARL-CR-301). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.
- Wagner, M., & Adkins, R. (30 June 1994). HARDMAN III analysis of soldier as a system (SAAS) (E-1816U). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

APPENDIX A

MCCRACKEN-ALDRICH WORKLOAD SCALES

MCCRACKEN-ALDRICH WORKLOAD SCALES

McCracken-Aldrich Scale Values

Scale Value	Descriptor	Scale
0.0	No Visual Activity	Visual
1.0	Visually Register/Detect (detect occurrence of image)	
3.7	Visually Discriminate (detect visual difference)	
4.0	Visually Inspect/Check (discrete inspection/static condition)	
5.0	Visually Locate/Align (selective orientation)	
5.4	Visually Track/Follow (maintain orientation)	
5.9	Visually Read (symbol)	
7.0	Visually Scan/Search/Monitor (continuous/serial inspection, multiple conditions)	
0.0	No Cognitive Activity	Cognitive
1.0	Automatic (simple association)	
1.2	Alternative selection	
3.7	Sign/Signal Recognition	
4.6	Evaluation/Judgment (consider single aspect)	
5.3	Encoding/Decoding, Recall	
6.8	Evaluation/Judgment (consider several aspects)	
7.0	Estimation, Calculation, Conversion	
0.0	No Auditory Activity	Auditory
1.0	Detect/Register Sound (detect occurrence of sound)	
2.0	Orient to Sound (general orientation/attention)	
4.2	Orient to Sound (selective orientation/attention)	
4.3	Verify Auditory Feedback (detect occurrence of anticipated sound)	
4.9	Interpret Semantic Content (speech)	
6.6	Discriminate Sound Characteristics (detect auditory differences)	
7.0	Interpret Sound Patterns (pulse rates, etc.)	
0.0	No Psychomotor Activity	Psychomotor
1.0	Speech	
2.2	Discrete Actuation (button, toggle, trigger)	
2.6	Continuous Adjustive (flight control, sensor control)	
4.6	Manipulative	
5.8	Discrete Adjustive (rotary, vertical thumb wheel, lever position)	
6.5	Symbolic Production (writing)	
7.0	Serial Discrete Manipulation (keyboard entries)	

APPENDIX B

WORKLOAD BREAKDOWN BY SENSORY FEEDBACK TYPE

WORKLOAD BREAKDOWN BY SENSORY FEEDBACK TYPE

Key:

OB - On-Board Driving

LL - Low Level Feedback BI - Binaural Feedback

FF - Force Feedback

ST - Stereo Vision

WF - Wide Field of View

AF - All Feedback Combined

Note. In the following tables, blank data spaces signify data from the Low Level Feedback condition that did not change as a result of the sensory feedback mode.

Function 1: Move to Area of Operations (dummy function)

Function 2: Conduct Surveillance

Tasks:

1. Conduct Surveillance (dummy)

2. Detection of Status Change

	LL	OB	BI	FF	ST	WF	AF
AUD							
COG	4.6	3.7					4.6
PSYM							
VIS	3.7	1					3.7
Most Likely Time to Complete (s)	1.5	1.0				1.2	1.2
Fastest Time to Compete (s)	1.2	.6				1.0	1.0

3. Alerted by External Source

	LL	OB	BI	FF	ST	WF	AF
AUD			4.7				4.7
COG	4.6	3.7	3.7				3.7
PSYM							
VIS	5	3.7	5				5
Most Likely Time to Complete (s)	1.2	1.0					1.2
Fastest Time to Compete (s)	1.0	.6					1.0

4. Type of Change (dummy)

5. Course (dummy)

6. Is Course in FOV?

	LL	OB	BI	FF	ST	WF	AF
AUD							
COG	6.8	3.7			6.8	4.6	4.6
PSYM							
VIS	7	3.7			5	5.4	5
Most Likely Time to Complete (s)	1.2	1.0			1.0		1.0
Fastest Time to Compete (s)	1.0	.6			.9		.9

7. Course Not in FOV

	LL	OB	BI	FF	ST	WF	AF
AUD							
COG	6.8	3.7			6.8	4.6	4.6
PSYM							
VIS	7	3.7			5	5.4	5
Most Likely Time to Complete (s)	1.5	1.0			1.2	1.0	1.0
Fastest Time to Compete (s)	1.2	.6			1.0	.9	.9

8. Alter Vehicle Orientation		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	3.7				5.3	5.3
	PSYM	2.6	1				2.6	2.6
	VIS	5.4	3.7				5.4	5.4
Most Likely Time to Complete (s)		4.8	2.5					4.8
Fastest Time to Compete (s)		2.5	1.0					2.5
9. Course in FOV (dummy)								
10. Search (dummy)								
11. Visual (dummy)								
12. Look Up		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	3.7			5.3	4.6	4.6
	PSYM	1	1			1	1	1
	VIS	7	3.7			5.9	5.4	5.4
Most Likely Time to Complete (s)		1.5	1.0			1.2	1.0	1.0
Fastest Time to Compete (s)		1.2	.6			1.0	.9	.9
13. Look Down		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	3.7			5.3	4.6	4.6
	PSYM	1	1			1	1	1
	VIS	7	3.7			5.9	5.4	5.4
Most Likely Time to Complete (s)		1.5	1.0			1.2	1.0	1.0
Fastest Time to Compete (s)		1.2	.6			1.0	.9	.9
14. Look Left		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	3.7			5.3	4.6	4.6
	PSYM	1	1			1	1	1
	VIS	7	3.7			5.9	5.4	5.4
Most Likely Time to Complete (s)		1.5	1.0			1.2	1.0	1.0
Fastest Time to Compete (s)		1.2	.6			1.0	.9	.9
15. Look Right		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	3.7			5.3	4.6	4.6
	PSYM	1	1			1	1	1
	VIS	7	3.7			5.9	5.4	5.4
Most Likely Time to Complete (s)		1.5	1.0			1.2	1.0	1.0
Fastest Time to Compete (s)		1.2	.6			1.0	.9	.9
16. Auditory		LL	OB	BI	FF	ST	WF	AF
	AUD			2				2
	COG			1				1
	PSYM							
	VIS							
Most Likely Time to Complete (s)		1.2	1.0					1.2
Fastest Time to Compete (s)		1.0	.6					1.0
17. Dummy								

18. ID Course?		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	3.7			5.3	4.6	4.6
	PSYM							
	VIS	5	3.7			5	5.4	5
Most Likely Time to Complete (s)		1.5	1.0			1.2	1.0	1.0
Fastest Time to Compete (s)		1.2	.6			1.0	.9	.9
19. Does ID Course		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	3.7			4.6	4.6	4.6
	PSYM							
	VIS	5	3.7			5	5.4	5
Most Likely Time to Complete (s)		1.5	1.0			1.2	1.0	1.0
Fastest Time to Compete (s)		1.2	.6			1.0	.9	.9
20. Does Not ID Course		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	3.7			4.6	4.6	4.6
	PSYM							
	VIS	5	3.7			5	5.4	5
Most Likely Time to Complete (s)		1.5	1.0			1.2	1.0	1.0
Fastest Time to Compete (s)		1.2	.6			1.0	.9	.9
21. On Course		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG							
	PSYM							
	VIS							
Most Likely Time to Complete (s)		1.5	1.0			1.2	1.0	1.0
Fastest Time to Compete (s)		1.2	.6			1.0	.9	.9
22. Not on Course		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	3.7			4.6		4.6
	PSYM							
	VIS	5.4	3.7			5.4		5.4
Most Likely Time to Complete (s)		1.5	1.0			1.2	1.0	1.0
Fastest Time to Compete (s)		1.2	.6			1.0	.9	.9
23. Consult Navigational Aid		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	7	3.7					7
	PSYM							
	VIS	7	7					7
Most Likely Time to Complete (s)		1.2	1.0					1.2
Fastest Time to Compete (s)		1.0	.6					1.0
24. ID Potential Obstacles/Hazards?		LL	OB	BI	FF	ST	WF	AF
	AUD			2				2
	COG	6.8	3.7	6.8		4.6		4.6
	PSYM							
	VIS	7	5.9	5.4		5.9		5.9
Most Likely Time to Complete (s)		1.5	1.0			1.2		1.2
Fastest Time to Compete (s)		1.2	.6			1.0		1.0

25. Does ID Hazards		LL	OB	BI	FF	ST	WF	AF
	AUD			2				2
	COG	6.8	3.7	6.8		4.6		4.6
	PSYM							
	VIS	7	5.9	5.4		5.9		5.4
Most Likely Time to Complete (s)		1.5	1.0			1.2		1.2
Fastest Time to Compete (s)		1.2	.6			1.0		1.0
26. Does Not ID Hazards		LL	OB	BI	FF	ST	WF	AF
	AUD			2				2
	COG	6.8	3.7	6.8		4.6		4.6
	PSYM							
	VIS	7	5.9	5.4		5.9		5.4
Most Likely Time to Complete (s)		1.5	1.0			1.2		1.2
Fastest Time to Compete (s)		1.2	.6			1.0		1.0
27. Hazard Immediate Threat?		LL	OB	BI	FF	ST	WF	AF
	AUD			2				2
	COG	6.8	3.7	6.8		4.6		4.6
	PSYM							
	VIS	7	5.9	5.4		5.9		5.4
Most Likely Time to Complete (s)		1.2	1.0			1.0		1.0
Fastest Time to Compete (s)		1.0	.6			.9		.9
28. Immediate Threat, Alter Course		LL	OB	BI	FF	ST	WF	AF
	AUD			2				2
	COG	7	3.7	4.6				4.6
	PSYM	2.6	2.6	2.6				2.6
	VIS							
Most Likely Time to Complete (s)		3.5	1.8					3.5
Fastest Time to Compete (s)		1.5	.9					1.5
29. Not Immediate Threat		LL	OB	BI	FF	ST	WF	AF
	AUD			2				2
	COG	7	3.7	4.6				4.6
	PSYM							
	VIS							

Function 3: Monitor Vehicle Instruments

Tasks:

1. Monitor Instruments (dummy)
2. Frequent (dummy)
3. Infrequent (dummy)
4. Monitor Speedometer

		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	5.3						5.3
	PSYM							
	VIS	4						4
5. Monitor Tachometer		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	5.3						5.3
	PSYM							
	VIS	4						4

6. Monitor Fuel Level		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	4.6						4.6
	PSYM							
	VIS	4						4
7. Monitor Oil Pressure		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	4.6						4.6
	PSYM							
	VIS	4						4
8. Monitor Engine Temperature		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	4.6						4.6
	PSYM							
	VIS	4						4
9. Monitor Battery Voltage		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	4.6						4.6
	PSYM							
	VIS	4						4
10. Verify Normal Range		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	4.6						4.6
	PSYM							
	VIS	4						4
11. Normal Range		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	4.6						4.6
	PSYM							
	VIS	4						4
12. Not Normal Range		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	4.6						4.6
	PSYM							
	VIS	4						4
13. Stop Vehicle and Monitor		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1.2	1.2					1.2
	PSYM	2.2						2.2
	VIS	7.0	3.7					7.0
Most Likely Time to Complete (s)		10.0	5.0					10.0
Fastest Time to Compete (s)		7.0	1.8					7.0

Function 4: Monitor Vehicle Status
Tasks:

1. Monitor Vehicle Status (dummy)								
2. Monitor Vehicle Pitch		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	1				4.6	4.6
	PSYM							
	VIS	5	3.7				5	5
	Most Likely Time to Complete (s)	1.8	1.0				1.3	1.3
	Fastest Time to Compete (s)	1.2	.6				1.0	1.0
3. Monitor Vehicle Roll		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	1				4.6	4.6
	PSYM							
	VIS	5	3.7				5	5
	Most Likely Time to Complete (s)	1.8	1.0				1.3	1.3
	Fastest Time to Compete (s)	1.2	.6				1.0	1.0
4. Vehicle Attitude in Normal Range?			LL	OB	BI	FF	ST	WF
AF								
	AUD							
	COG	6.8	1				4.6	4.6
	PSYM							
	VIS	5	3.7				5	5
	Most Likely Time to Complete (s)	2.4	1.0					2.4
	Fastest Time to Compete (s)	1.2	.6					1.2
5. Normal		LL	OB	BI	FF	ST	WF	AF
	AUD		4.3	1				1
	COG	4.6	4.6	4.6				4.6
	PSYM							
	VIS	5.9	5.9	5.9				5.9
	Most Likely Time to Complete (s)	1.6	1.0					1.6
	Fastest Time to Compete (s)	1.2	.6					1.2
6. Not Normal		LL	OB	BI	FF	ST	WF	AF
	AUD		4.3	1				1
	COG	4.6	4.6	4.6				4.6
	PSYM							
	VIS	5.9	5.9	5.9				5.9
	Most Likely Time to Complete (s)	1.6	1.0					1.6
	Fastest Time to Compete (s)	1.2	.6					1.2
7. Stop Vehicle, Correct Vehicle Attitude		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	4.6					6.8
	PSYM	2.6	2.6					2.6
	VIS	5.4	3.7					5.4
	Most Likely Time to Complete (s)	18.0	12.0					18.0
	Fastest Time to Compete (s)	15.0	6.0					15.0

8. Monitor Engine Speed		LL	OB	BI	FF	ST	WF	AF
	AUD		4.3	1				1
	COG	3.7	3.7	3.7				3.7
	PSYM							
	VIS	5.9	5.9	5.9				5.9
Most Likely Time to Complete (s)		1.6	1.0	1.2				1.2
Fastest Time to Compete (s)		1.2	.6	1.0				1.0
9. Engine Speed in Normal Operation?		LL	OB	BI	FF	ST	WF	AF
	AUD		4.3	1				1
	COG	4.6	3.7					4.6
	PSYM							
	VIS	5.9	5.9					5.9
Most Likely Time to Complete (s)		1.6	1.0	1.2				1.2
Fastest Time to Compete (s)		1.2	.6	1.0				1.0
10. Normal		LL	OB	BI	FF	ST	WF	AF
	AUD		4.3	1				1
	COG	4.6	4.6	4.6				4.6
	PSYM							
	VIS	5.9	5.9	5.9				5.9
Most Likely Time to Complete (s)		1.6	1.0	1.2				1.2
Fastest Time to Compete (s)		1.2	.6	1.0				1.0
11. Not Normal		LL	OB	BI	FF	ST	WF	AF
	AUD		4.3	1				1
	COG	4.6	4.6	4.6				4.6
	PSYM							
	VIS	5.9	5.9	5.9				5.9
Most Likely Time to Complete (s)		1.6	1.0	1.2				1.2
Fastest Time to Compete (s)		1.2	.6	1.0				1.0
12. Slow or Stop Vehicle and Check		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1.2						1.2
	PSYM	2.6						2.6
	VIS							
13. Monitor Ground Surface		LL	OB	BI	FF	ST	WF	AF
	AUD		4.3	4.3				4.3
	COG	3.7	3.7	3.7				3.7
	PSYM							
	VIS	4	3.7	5				4
Most Likely Time to Complete (s)		1.6		1.2			1.0	1.0
Fastest Time to Compete (s)		1.2		1.0			.9	.9
14. Ground Surface Suitable for Travel?		LL	OB	BI	FF	ST	WF	AF
	AUD		4.3	4.3				4.3
	COG	6.8	3.7	4.6		5.3		4.6
	PSYM							
	VIS	4	3.7	4		4		4
Most Likely Time to Complete (s)		1.6		1.2			1.0	1.0
Fastest Time to Compete (s)		1.2		1.0			.9	.9

15. Suitable		LL	OB	BI	FF	ST	WF	AF
	AUD		4.3	4.3				4.3
	COG	6.8	3.7	4.6		5.3		4.6
	PSYM							
	VIS	4	3.7	4		4		4
	Most Likely Time to Complete (s)	1.6		1.2			1.0	1.0
	Fastest Time to Compete (s)	1.2		1.0			.9	.9
16. Not Suitable		LL	OB	BI	FF	ST	WF	AF
	AUD		4.3	4.3				4.3
	COG	6.8	3.7	4.6		5.3		4.6
	PSYM							
	VIS	4	3.7	4		4		4
	Most Likely Time to Complete (s)	1.6		1.2			1.0	1.0
	Fastest Time to Compete (s)	1.2		1.0			.9	.9
17. Change Course		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1	1					1
	PSYM	2.6	2.6					2.6
	VIS	5.4	3.7					5.4
	Most Likely Time to Complete (s)	3.0	1.5					3.0
	Fastest Time to Compete (s)	1.2	1					1.2
18. (dummy)								

Function 5: Perform Self Recovery

Tasks:

1. Perform Self-Recovery		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	3.7				4.6	4.6
	PSYM	4.6	2.6					2.6
	VIS	7	5				5.4	5.4
2. Need to Change Direction?		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	7	3.7			5.3	4.6	4.6
	PSYM							
	VIS	7	5			5.4	7	5.4
	Most Likely Time to Complete (s)	1.8	1.0			1.2		1.2
	Fastest Time to Compete (s)	1.2	.6			1.0		1.0
3. Change Needed (dummy)								
4. Look to Sides Estimate Correction		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	3.7			5.3	4.6	4.6
	PSYM	1	1			1	1	1
	VIS	7	5			5.4	7	5.4
	Most Likely Time to Complete (s)	1.4	1.0			1.0		1.0
	Fastest Time to Compete (s)	1.25	.6			.9		.9

5. Change Not Needed		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1.2						1.2
	PSYM							
	VIS							
	Most Likely Time to Complete (s)	1.8	1.0					1.8
	Fastest Time to Compete (s)	1.2	.6					1.2
6. Need to Reverse Direction?		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1.2						1.2
	PSYM							
	VIS							
	Most Likely Time to Complete (s)	1.2	1.0					1.2
	Fastest Time to Compete (s)	1.2	.6					1.2
7. Reverse Needed		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1.2						1.2
	PSYM							
	VIS							
	Most Likely Time to Complete (s)	1.2	1.0					1.2
	Fastest Time to Compete (s)	1.2	.6					1.2
8. Look to Rear, Back-up		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	3.7			5.3		5.3
	PSYM	2.6						2.6
	VIS	7	5			5.4		5.4
	Most Likely Time to Complete (s)	14.0	6.0				10.0	10.0
	Fastest Time to Compete (s)	8.0	3.0				5.0	5.0
9. Change Direction		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1.2						1.2
	PSYM	2.6						2.6
	VIS							
	Most Likely Time to Complete (s)	4.2	2.0				3.0	3.0
	Fastest Time to Compete (s)	2.0	.9				1.5	1.5
10. Reverse Not Needed		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1.2						1.2
	PSYM							
	VIS							
	Most Likely Time to Complete (s)	1.2	1.0					1.2
	Fastest Time to Compete (s)	1.0	.6					1.0
11. Proceed (dummy)								

Function 6: Nothing Happens (dummy)

Function 7: Steer Vehicle**Tasks:**

1. Steer Vehicle (dummy)

2. Steer Right		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1	1		1		1	1
	PSYM	2.6	2.6		2.6		2.6	2.6
	VIS	5.4	3.7		4		5	4
Most Likely Time to Complete (s)		1.3			1.0			1.0
Fastest Time to Compete (s)		.95			.8			.8
3. Steer Left		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1	1		1		1	1
	PSYM	2.6	2.6		2.6		2.6	2.6
	VIS	5.4	3.7		4		5	4
Most Likely Time to Complete (s)		1.3			1.0			1.0
Fastest Time to Compete (s)		.95			.8			.8
4. Hold Straight		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1	1		1			1
	PSYM	2.6	2.6		2.6			2.6
	VIS	5.4	3.7		4			4
Most Likely Time to Complete (s)		1.3			1.0			1.0
Fastest Time to Compete (s)		.95			.8			.8
5. Let Steering Self-Center		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG							
	PSYM	1			1			1
	VIS	1			4			4
Most Likely Time to Complete (s)		1.3			1.0			1.0
Fastest Time to Compete (s)		.95			.8			.8
6. Verify Center Position		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	6.8	1		6.8		4.6	4.6
	PSYM							
	VIS	5.4	3.7		4		5	4
Most Likely Time to Complete (s)		2.5			1.0		1.5	1.0
Fastest Time to Compete (s)		1.2			.8		1.2	.8
7. Verify Steering Control Action		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	4.6	1				4.6	4.6
	PSYM							
	VIS	5.4	3.7				5	5
Most Likely Time to Complete (s)		2.0	1.2				1.2	
Fastest Time to Compete (s)		1.2	1.0				1.0	

Function 8: Power Vehicle
Tasks:

1. Power Vehicle (dummy)

2. Accelerator (dummy)

3. Apply Accelerator		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1						1
	PSYM	2.6						2.6
	VIS	1						1

Most Likely Time to Complete (s)		1.3	1.2					1.3
Fastest Time to Compete (s)		1.0	.6					1.0

4. Hold Accelerator		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1						1
	PSYM	2.6						2.6
	VIS	1						1

Most Likely Time to Complete (s)		1.3	1.2					1.3
Fastest Time to Compete (s)		1.0	.6					1.0

5. Let Off Accelerator		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1						1
	PSYM	2.6						2.6
	VIS	1						1

Most Likely Time to Complete (s)		1.3	1.2					1.3
Fastest Time to Compete (s)		1.0	.6					1.0

6. Verify Accelerator Action		LL	OB	BI	FF	ST	WF	AF
	AUD		4.3	1				1
	COG	4.6	1	3.7				3.7
	PSYM							
	VIS	3.7	3.7	3.7				3.7

Most Likely Time to Complete (s)		1.3		1.0				1.0
Fastest Time to Compete (s)		.95		.8				.8

7. Brake (dummy)

Most Likely Time to Complete (s)		1.3	1.2
Fastest Time to Compete (s)		1.0	.6

8. Apply Brake		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1						1
	PSYM	2.6						2.6
	VIS	1						1

Most Likely Time to Complete (s)		1.3	1.2					1.3
Fastest Time to Compete (s)		1.0	.6					1.0

9. Hold Brake		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1						1
	PSYM	2.6						2.6
	VIS	1					1	
	Most Likely Time to Complete (s)	1.3	1.2					1.3
	Fastest Time to Compete (s)	1.0	.6					1.0
10. Let Off Brake		LL	OB	BI	FF	ST	WF	AF
	AUD							
	COG	1						1
	PSYM	2.6						2.6
	VIS	1					1	
	Most Likely Time to Complete (s)	1.3	1.2					1.3
	Fastest Time to Compete (s)	1.0	.6					1.0
11. Verify Brake Action		LL	OB	BI	FF	ST	WF	AF
	AUD		4.3	1				1
	COG	4.6	1	3.7				3.7
	PSYM							
	VIS	3.7	3.7	3.7				3.7
	Most Likely Time to Complete (s)	1.3	1.0					1.3
	Fastest Time to Compete (s)	.95	.8					.8

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
2	ADMINISTRATOR DEFENSE TECHNICAL INFO CENTER ATTN DTIC DDA 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218	1	HEADQUARTERS USATRADO ATTN ATCD SP FORT MONROE VA 23651
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL OP SD TA/ RECORDS MANAGEMENT 2800 POWDER MILL RD ADELPHI MD 20783-1197	1	COMMANDER USATRADO COMMAND SAFETY OFFICE ATTN ATOS (MR PESSAGNO/MR LYNE) FORT MONROE VA 23651-5000
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL OP SD TL/ TECHNICAL LIBRARY 2800 POWDER MILL RD ADELPHI MD 207830-1197	1	COMMANDER US ARMY MATERIEL COMMAND ATTN AMCAM 5001 EISENHOWER AVENUE ALEXANDRIA VA 22333-0001
1	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL OP SD TP/ TECH PUBLISHING BRANCH 2800 POWDER MILL RD ADELPHI MD 20783-1197	1	COMMANDER USA OPERATIONAL TEST & EVAL AGENCY ATTN CSTE TSM 4501 FORD AVE ALEXANDRIA VA 22302-1458
1	DIRECTORATE FOR MANPRINT ATTN DAPE MR DEPUTY CHIEF OF STAFF PERSONNEL 300 ARMY PENTAGON WASHINGTON DC 20310-0300	1	USA BIOMEDICAL R&D LABORATORY ATTN LIBRARY FORT DETRICK BUILDING 568 FREDERICK MD 21702-5010
1	CODE 1142PS OFFICE OF NAVAL RESEARCH 800 N QUINCY STREET ARLINGTON VA 22217-5000	1	HQ USAMRDC ATTN SGRD PLC FORT DETRICK MD 21701
1	DR ARTHUR RUBIN NATL INST OF STANDARDS & TECH BUILDING 226 ROOM A313 GAITHERSBURG MD 20899	1	COMMANDER USA AEROMEDICAL RESEARCH LAB ATTN LIBRARY FORT RUCKER AL 36362-5292
1	COMMANDER US ARMY RESEARCH INSTITUTE ATTN PERI ZT (DR E M JOHNSON) 5001 EISENHOWER AVENUE ALEXANDRIA VA 22333-5600	1	US ARMY SAFETY CENTER ATTN CSSC SE FORT RUCKER AL 36362
1	DEPUTY COMMANDING GENERAL ATTN EXS (Q) MARINE CORPS RD&A COMMAND QUANTICO VA 22134	1	CHIEF ARMY RESEARCH INSTITUTE AVIATION R&D ACTIVITY ATTN PERI IR FORT RUCKER AL 36362-5354
		1	TECHNICAL INFORMATION CENTER HQS TRADO TEST & EXPERIMENTATION CMD EXPERIMENTATION CENTER BLDG 2925 FORT ORD CA 93941-7000

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	AAMRL/HE WRIGHT PATTERSON AFB OH 45433-6573	1	COMMANDER WHITE SANDS MISSILE RANGE ATTN TECHNICAL LIBRARY WHITE SANDS MISSILE RANGE NM 88002
1	US ARMY NATICK RD&E CENTER ATTN STRNC YBA NATICK MA 01760-5020	1	STRICOM 12350 RESEARCH PARKWAY ORLANDO FL 32826-3276
1	US ARMY TROOP SUPPORT CMD NATICK RD&E CENTER ATTN BEHAVIORAL SCI DIV SSD NATICK MA 01760-5020	1	COMMANDER USA TANK-AUTOMOTIVE R&D CENTER ATTN AMSTA RS/D REES WARREN MI 48090
1	US ARMY TROOP SUPPORT CMD NATICK RD&E CENTER ATTN TECH LIBRARY (STRNC MIL) NATICK MA 01760-5040	1	COMMANDER USA TANK-AUTOMOTIVE R&D CENTER ATTN AMSTA TSL (TECH LIBRARY) WARREN MI 48397-5000
1	HQ USA RESEARCH INST OF ENVIRONMENTAL MEDICINE ATTN MEDRI CL (DR J KOBRICK) NATICK MA 01760-5007	1	COMMANDER USA COLD REGIONS TEST CENTER ATTN STECR TS A APO AP 96508-7850
1	DR RICHARD JOHNSON HEALTH & PERFORMANCE DIVISION US ARIEM NATICK MA 01760-5007	1	US ARMY RSCH DEV STDZN GP-UK ATTN DR MIKE STOUT PSC 802 BOX 15 FPO AE 09499-1500
1	USAF ARMSTRONG LAB/CFTO ATTN DR F WESLEY BAUMGARDNER SUSTAINED OPERATIONS BRANCH BROOKS AFB TX 78235-5000	1	PURDUE UNIVERSITY SERIALS UNIT CDM KARDEX 1535 STEWART CENTER WEST LAFAYETTE IN 47907-1535
1	DR JON FALLESEN ARI FIELD UNIT PO BOX 3407 FORT LEAVENWORTH KS 66027-0347	1	GOVT PUBLICATIONS LIBRARY 409 WILSON M UNIVERSITY OF MINNESOTA MINNEAPOLIS MN 55455
1	ARI FIELD UNIT FORT KNOX BUILDING 2423 PERI IK FORT KNOX KY 40121-5620	1	DR HARVEY A TAUB RSCH SECTION PSYCH SECTION VETERANS ADMIN HOSPITAL IRVING AVENUE & UNIVERSITY PLACE SYRACUSE NY 13210
1	COMMANDANT USA ARTILLERY & MISSILE SCHOOL ATTN USAAMS TECH LIBRARY FORT SILL OK 73503	1	DR ANTHONY DEBONS IDIS UNIVERSITY OF PITTSBURGH PITTSBURGH PA 15260
1	COMMANDER WHITE SANDS MISSILE RANGE ATTN STEWS TE RE WHITE SANDS MISSILE RANGE NM 88002	1	DR ROBERT KENNEDY ESSEX CORPORATION SUITE 227 1040 WOODCOCK ROAD ORLANDO FL 32803

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	DR NANCY ANDERSON DEPARTMENT OF PSYCHOLOGY UNIVERSITY OF MARYLAND COLLEGE PARK MD 20742	1	MR WALT TRUSZKOWSKI CODE 522.3 NASA/GODDARD SPACE FLIGHT CENTER GREENBELT MD 20771
1	MR LARRY W AVERY BATTELLE PACIFIC NW LABS PO BOX 999 MAIL STOP K6-66 RICHLAND WA 99352	1	DR TOM MALONE CARLOW ASSOCIATES INC SUITE 750 3141 FAIRVIEW PARK DRIVE FAIRFAX VA 22042
1	LIBRARY ESSEX CORPORATION SUITE 510 1430 SPRING HILL ROAD MCLEAN VA 22102-3000	1	COMMANDER US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE NATICK MA 01760-5007
1	DR BEN B MORGAN DEPARTMENT OF PSYCHOLOGY UNIVERSITY OF CENTRAL FLORIDA PO BOX 25000 ORLANDO FL 32816	1	DR DANIEL J POND BATTELLE PNL/K6-66 PO BOX 999 RICHLAND WA 99350
1	LAWRENCE C PERLMUTER PHD UNIV OF HEALTH SCIENCES THE CHICAGO MEDICAL SCHOOL DEPT OF PSYCHOLOGY 3333 GREEN BAY ROAD NORTH CHICAGO IL 60064	1	HUMAN FACTORS ENG PROGRAM DEPT OF BIOMEDICAL ENGINEERING COLLEGE OF ENGINEERING & COMPUTER SCIENCE WRIGHT STATE UNIVERSITY DAYTON OH 45435
1	MR AJ ARNOLD STAFF PROJECT ENG HUMAN FACTORS DEPARTMENT GENERAL MOTORS SYSTEMS ENG 1151 CROOKS ROAD TROY MI 48084	1	PEO ARMORED SYS MODERNIZATION US ARMY TANK-AUTOMOTIVE CMD ATTN SFAE ASM S WARREN MI 48397-5000
1	GENERAL DYNAMICS LAND SYSTEMS DIV LIBRARY PO BOX 1901 WARREN MI 48090	1	PEO COMBAT SUPPORT ATTN AMCPEO CS US ARMY TANK AUTOMOTIVE CMD WARREN MI 48397-5000
1	DR LLOYD A AVANT DEPARTMENT OF PSYCHOLOGY IOWA STATE UNIVERSITY AMES IA 50010	1	PEO INTELLIGENCE & ELECTRONIC WARFARE ATTN AMCPEO IEW VINT HILL FARMS STATION BLDG 197 WARRENTON VA 22186-5115
1	DR MM AYOUB DIRECTOR INST FOR ERGONOMICS RESEARCH TEXAS TECH UNIVERSITY LUBBOCK TX 79409	1	DENNIS L SCHMICKLY CREW SYSTEMS ENGINEERING MCDONNELL DOUGLAS HELICOPTER 5000 EAST MCDOWELL ROAD MESA AZ 85205-9797
1	MR KENNETH C CROMBIE TECHNICAL LIBRARIAN E104 DELCO SYSTEMS OPERATIONS 6767 HOLLISTER AVENUE GOLETA CA 93117	1	JON TATRO HUMAN FACTORS SYSTEM DESIGN BELL HELICOPTER TEXTRON INC PO BOX 482 MAIL STOP 6 FT WORTH TX 76101

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	CHIEF CREW SYSTEMS INTEGRATION SIKORSKY AIRCRAFT M/S S3258 NORTH MAIN STREET STRATFORD CT 06602	1	HQ US SPECIAL OPERATIONS CMD AMC FAST SCIENCE ADVISER ATTN SOSD MACDILL AIR FORCE BASE TAMPA FL 33608-0442
1	OASD (FM&P) WASHINGTON DC 20301-4000	1	HQ US ARMY EUROPE AND 7TH ARMY ATTN AEAGX SA OFFICE OF THE SCIENCE ADVISER APO AE 09014
1	COMMANDER MARINE CORPS SYSTEMS COMMAND ATTN CBGT QUANTICO VA 22134-5080	1	COMMANDER HQ 21ST THEATER ARMY AREA CMD AMC FAST SCIENCE ADVISER ATTN AERSA APO AE 09263
1	DIRECTOR AMC-FIELD ASSIST IN SCIENCE & TECHNOLOGY ATTN AMC-FAST (RICHARD FRANSEEN) FT BELVOIR VA 22060-5606	1	COMMANDER HEADQUARTERS USEUCOM AMC FAST SCIENCE ADVISER UNIT 30400 BOX 138 APO AE 09128
1	COMMANDER US ARMY FORCES COMMAND ATTN FCDJ SA BLDG 600 AMC FAST SCIENCE ADVISER FT MCPHERSON GA 30330-6000	1	HQ 7TH ARMY TRAINING COMMAND UNIT #28130 AMC FAST SCIENCE ADVISER ATTN AETT SA APO AE 09114
1	COMMANDER I CORPS AND FORT LEWIS AMC FAST SCIENCE ADVISER ATTN AFZH CSS FORT LEWIS WA 98433-5000	1	COMMANDER HHC SOUTHERN EUROPEAN TASK FORCE ATTN AESE SA BUILDING 98 AMC FAST SCIENCE ADVISER APO AE 09630
1	HQ III CORPS & FORT HOOD OFFICE OF THE SCIENCE ADVISER ATTN AFZF CS SA FORT HOOD TX 76544-5056	1	COMMANDER US ARMY PACIFIC AMC FAST SCIENCE ADVISER ATTN APSA FT SHAFTER HI 96858-5L00
1	COMMANDER U.S. ARMY NATL TRAINING CENTER AMC FAST SCIENCE ADVISER ATTN AMXLA SA FORT IRWIN CA 92310	1	COMMANDER US ARMY JAPAN/IX CORPS UNIT 45005 ATTN APAJ SA AMC FAST SCIENCE ADVISERS APO AP 96343-0054
1	COMMANDER HQ XVIII ABN CORPS & FORT BRAGG OFFICE OF THE SCI ADV BLDG 1-1621 ATTN AFZA GD FAST FORT BRAGG NC 28307-5000	1	AMC FAST SCIENCE ADVISERS PCS #303 BOX 45 CS-SO APO AP 96204-0045
1	SOUTHCOM WASHINGTON FIELD OFC 1919 SOUTH EADS ST SUITE L09 AMC FAST SCIENCE ADVISER ARLINGTON VA 22202	1	COMMANDER ALASKAN COMMAND ATTN SCIENCE ADVISOR (MR GRILLS) 6-900 9TH ST STE 110 ELMENDORF AFB ALASKA 99506

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	DR SEHCHANG HAH DEPT OF BEHAVIORAL SCIENCES & LEADERSHIP BUILDING 601 ROOM 281 US MILITARY ACADEMY WEST POINT NEW YORK 10996-1784	1	CHIEF ARL HRED STRICOM FIELD ELEMENT ATTN AMSRL HR MT (A GALBAVY) 12350 RESEARCH PARKWAY ORLANDO FL 32826-3276
1	US ARMY RESEARCH INSTITUTE ATTN PERI IK (DOROTHY L FINLEY) 2423 MORANDE STREET FORT KNOX KY 40121-5620	1	CHIEF ARL HRED FT HOOD FIELD ELEMENT ATTN AMSRL HR MA (E SMOOTZ) HQ TEXCOM BLDG 91012 RM 134 FT HOOD TX 76544-5065
1	CHIEF ARL HRED ARDEC FIELD ELEMENT ATTN AMSRL HR MG (R SPINE) BUILDING 333 PICATINNY ARSENAL NJ 07806-5000	1	USARL HRED FIELD ELEMENT USAADASCH ATTN ATSA CD ATTN AMSRL HR ME (K REYNOLDS) 5800 CARTER ROAD FORT BLISS TX 79916-3802
1	CHIEF ARL HRED ATCOM FIELD ELEMENT ATTN AMSRL HR MI (A MANCE) 4300 GOODFELLOW BLVD BLDG 105 1ST FLOOR POST A-7 ST LOUIS MO 63120-1798	1	CHIEF ARL HRED ARMC FIELD ELEMENT ATTN AMSRL HR MH (M BENEDICT) BUILDING 1109D (BASEMENT) FT KNOX KY 40121-5215
1	CHIEF ARL HRED FIELD ELEMENT AT FORT BELVOIR STOP 5850 ATTN AMSRL HR MK (P SCHOOL) 10109 GRIDLEY ROAD SUITE A102 FORT BELVOIR VA 22060-5850	1	CHIEF ARL HRED USAFAS FIELD ELEMENT ATTN AMSRL HR MF (L PIERCE) BLDG 3040 ROOM 220 FORT SILL OK 73503-5600
1	CHIEF ARL HRED CECOM FIELD ELEMENT ATTN AMSRL HR ML (J MARTIN) MYERS CENTER ROOM 3C214 FT MONMOUTH NJ 07703-5630	1	CHIEF ARL HRED USAIC FIELD ELEMENT ATTN AMSRL HR MW (E REDDEN) BUILDING 4 ROOM 349 FT BENNING GA 31905-5400
1	CHIEF ARL HRED MICOM FIELD ELEMENT ATTN AMSRL HR MO (T COOK) BUILDING 5400 ROOM C242 REDSTONE ARSENAL AL 35898-7290	1	CHIEF ARL HRED SC&FG FIELD ELEMENT ATTN AMSRL HR MS (L BUCKALEW) SIGNAL TOWERS ROOM 207 FORT GORDON GA 30905-5233
1	CHIEF ARL HRED TACOM FIELD ELEMENT ATTN AMSRL HR MU (M SINGAPORE) BUILDING 200A 2ND FLOOR WARREN MI 48397-5000	1	ARL HRED USASOC FIELD ELEMENT ATTN AMSRL HR MN (F MALKIN) BUILDING D3206 ROOM 503 FORT BRAGG NC 28307-5000
1	CHIEF ARL HRED AVNC FIELD ELEMENT ATTN AMSRL HR MJ (R ARMSTRONG) PO BOX 620716 BUILDING 514 FT RUCKER AL 36362-0716	1	ARL HRED VHFS FIELD ELEMENT ATTN AMSRL HR MX (T CLARK) BLDG 181 STOP 5 VINT HILL FARMS STA WARRENTON VA 22186-5116

NO. OF COPIES	ORGANIZATION
1	CHIEF ARL HRED FT HUACHUCA FIELD ELEMENT ATTN AMSRL HR MY BUILDING 84017 FORT HUACHUCA AZ 85613-7000
	<u>ABERDEEN PROVING GROUND</u>
5	DIRECTOR US ARMY RESEARCH LABORATORY ATTN AMSRL OP AP L (TECH LIB) BLDG 305 APG AA
1	ARL SLAD ATTN AMSRL BS (DR JT KLOPCIC) BLDG 328 APG-AA
1	LIBRARY ARL BUILDING 459 APG-AA
1	CHIEF ARL HRED ERDEC FIELD ELEMENT ATTN AMSRL HR MM (D HARRAH) BLDG 459 APG-AA
1	USMC LIAISON OFFICE ATTN AMST ML RYAN BUILDING APG-AA
1	USATECOM RYAN BUILDING APG-AA

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE September 1996		3. REPORT TYPE AND DATES COVERED Final	
4. TITLE AND SUBTITLE An Analysis of Teleoperation Workload in Various Sensory Feedback Modes				5. FUNDING NUMBERS PR: 1L162716AH70 PE: 6.27.16	
6. AUTHOR(S) Scribner, D. R.					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory Human Research & Engineering Directorate Aberdeen Proving Ground, MD 21005-5425				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory Human Research & Engineering Directorate Aberdeen Proving Ground, MD 21005-5425				10. SPONSORING/MONITORING AGENCY REPORT NUMBER ARL-TR-1114	
11. SUPPLEMENTARY NOTES					
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.				12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Recent quality increases of sensory feedback for teleoperation are allowing greater sensory immersion for the teleoperator. High speed and off-road driving conditions are critical teleoperator performance hurdles. The primary challenge to the development of good teleoperated systems is the basic driving task essential to the delivery of a mission package. The Human Research and Engineering Directorate of the U.S. Army Research Laboratory is involved with the advance of sensory feedback technologies in teleoperated systems and examines the effect of these technologies on teleoperator performance. Several driving models reflecting different sensory feedback modes were built in MAN-SEVAL, a module of HARDMAN III. Seven models were built in all, including one baseline model of on-board driving. The six other models consisted of low level feedback, binaural feedback, force feedback, stereovision, wide field of view, and all teleoperated feedback combined. These models have identical functional and task flow structures; however, task workloads were altered in each model, based upon the impact of the sensory feedback technology. The purpose of this effort was to 1) define the functions and tasks of the teleoperated driver, 2) formulate teleoperated driving models to assess the teleoperator's driving workload during varying sensory feedback conditions, and 3) develop a prediction tool for the impact of technology on teleoperator workload. Iterative model executions provided data that yielded significant differences between on-board and teleoperated workload as well as among workload for teleoperated models only.					
14. SUBJECT TERMS modeling teleoperation robotics workload				15. NUMBER OF PAGES 47	
				16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT		